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<b>TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371</b>		U.S. APPLICATION NO. (If Known, see 37 CFR 1.5) <b>10/069352</b>
INTERNATIONAL APPLICATION NO. PCT/US00/24000	INTERNATIONAL FILING DATE 31 August 2000	PRIORITY DATE CLAIMED 1 September 1999
TITLE OF INVENTION FAST WRITE INSTRUCTION FOR MICRO ENGINE USED IN MULTITHREADED PARALLEL PROCESSOR ARCHITECTURE		
APPLICANT(S) FOR DO/EO/US Gilbert Wolrich, Matthew J. Adiletta, William R. Wheeler, Debra Bernstein and Donald F. Hooper		
<p>Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:</p> <ol style="list-style-type: none"> <li>1. <input checked="" type="checkbox"/> This is a <b>FIRST</b> submission of items concerning a filing under 35 U.S.C. 371.</li> <li>2. <input type="checkbox"/> This is a <b>SECOND</b> or <b>SUBSEQUENT</b> submission of items concerning a filing under 35 U.S.C. 371.</li> <li>3. <input checked="" type="checkbox"/> This is an express request to promptly begin national examination procedures (35 U.S.C. 371(f)).</li> <li>4. <input checked="" type="checkbox"/> The US has been elected by the expiration of 19 months from the priority date (PCT Article 31).</li> <li>5. <input checked="" type="checkbox"/> A copy of the International Application as filed (35 U.S.C. 371(c)(2))           <ol style="list-style-type: none"> <li>a. <input checked="" type="checkbox"/> is attached hereto (required only if not communicated by the International Bureau).</li> <li>b. <input type="checkbox"/> has been communicated by the International Bureau.</li> <li>c. <input type="checkbox"/> is not required, as the application was filed in the United States Receiving Office (RO/US).</li> </ol> </li> <li>6. <input type="checkbox"/> An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).</li> <li>7. <input checked="" type="checkbox"/> Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))           <ol style="list-style-type: none"> <li>a. <input type="checkbox"/> are attached hereto (required only if not communicated by the International Bureau).</li> <li>b. <input type="checkbox"/> have been communicated by the International Bureau.</li> <li>c. <input type="checkbox"/> have not been made; however, the time limit for making such amendments has NOT expired.</li> <li>d. <input checked="" type="checkbox"/> have not been made and will not be made.</li> </ol> </li> <li>8. <input type="checkbox"/> An English language translation of amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).</li> <li>9. <input type="checkbox"/> An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).</li> <li>10. <input type="checkbox"/> An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).</li> </ol> <p><b>Items 11 to 16 below concern other documents or information included:</b></p> <ol style="list-style-type: none"> <li>11. <input checked="" type="checkbox"/> An Information Disclosure Statement under 37 CFR 1.97 and 1.98.</li> <li>12. <input type="checkbox"/> An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.</li> <li>13. <input type="checkbox"/> A FIRST preliminary amendment. <input type="checkbox"/> A SECOND or SUBSEQUENT preliminary amendment.</li> <li>14. <input type="checkbox"/> A substitute specification.</li> <li>15. <input type="checkbox"/> A change of power of attorney and/or address letter.</li> <li>16. <input type="checkbox"/> Other items or information:  <div style="margin-left: 20px;"> <input type="checkbox"/>  <input type="checkbox"/>  <input type="checkbox"/>  <input type="checkbox"/>  <input type="checkbox"/> </div> </li> </ol>		

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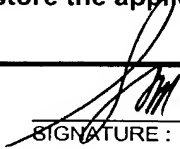
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Gabrielle Lewis

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U.S. APPLICATION NO. (IF KNOWN) <b>10/069352</b>		INTERNATIONAL APPLICATION NO. PCT/US00/24000		ATTORNEY'S DOCKET NUMBER 10559-308US1	
17. <input checked="" type="checkbox"/> The following fees are submitted:				<b>CALCULATIONS</b> PTO USE ONLY	
<b>Basic National Fee ( 37 CFR 1.492(a)(1)-(5) ):</b> Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO..... <b>\$1040</b>  International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO ..... <b>\$890</b>  International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO..... <b>\$740</b>  International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4)..... <b>\$710</b>  International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4) ..... <b>\$100</b>  <b>ENTER APPROPRIATE BASIC FEE AMOUNT =</b>					
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<input type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.				\$0.00	
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SEND ALL CORRESPONDENCE TO:					
Scott C. Harris FISH & RICHARDSON P.C. 4350 La Jolla Village Drive, Suite 500 San Diego, California 92122 (858) 678-5070 phone (858) 678-5099 facsimile					
SIGNATURE : 					
NAME <b>Scott C. Harris</b>					
REGISTRATION NUMBER <b>32,030</b>					

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APPLICATION  
FOR  
UNITED STATES LETTERS PATENT

TITLE: FAST WRITE INSTRUCTION FOR MICRO ENGINE USED  
IN MULTITHREADED PARALLEL PROCESSOR  
ARCHITECTURE

APPLICANT: GILBERT WOLRICH, MATTHEW J. ADILETTA,  
WILLIAM R. WHEELER, DEBRA BERNSTEIN AND  
DONALD F. HOOPER

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FAST WRITE INSTRUCTION FOR MICRO ENGINE USED  
IN MULTITHREADED PARALLEL PROCESSOR ARCHITECTURE

5

BACKGROUND

This invention relates to a memory instruction for computer processors.

Parallel processing is an efficient form of information processing of concurrent events in a computing process. Parallel processing demands concurrent execution of many programs in a computer, in contrast to sequential processing. In the context of a parallel processor, parallelism involves doing more than one thing at the same time. Unlike a serial paradigm where all tasks are performed sequentially at a single station or a pipelined machine where tasks are performed at specialized stations, with parallel processing, a number of stations are provided with each capable of performing all tasks. That is, in general all or a number of the stations work simultaneously and independently on the same or common elements of a problem. Certain problems are suitable for solution by applying parallel processing.

DESCRIPTION OF DRAWINGS

The foregoing features and other aspects of the invention will be described further in detail by the accompanying drawings, in which:

FIG. 1 is a block diagram of a communication system employing a hardware-based multithreaded processor.

FIG. 2 is a detailed block diagram of the hardware-based multithreaded processor of FIG. 1.

FIG. 3 is a block diagram of a micro engine functional unit employed in the hardware-based multithreaded processor of FIGS. 1 and 2.

FIG. 4 is a block diagram of a pipeline in the micro engine of FIG. 3.

FIG. 5 is a block diagram illustrating a format for arithmetic logic unit instruction results.

Like reference symbols in the various drawings indicate like elements.

## DETAILED DESCRIPTION

Referring to FIG. 1, a communication system 10 includes a parallel, hardware-based multithreaded processor 12. The hardware-based multithreaded processor 12 is coupled to a bus such as a PCI bus 14, a memory system 16 and a second bus 18. The system 10 is especially useful for tasks that can be broken into parallel subtasks or functions. Specifically, hardware-based multithreaded processor 12 is useful for tasks that are bandwidth oriented rather than latency oriented. The hardware-based multithreaded processor 12 has multiple micro engines 22 each with multiple hardware controlled threads that can be simultaneously active and independently work on a task.

The hardware-based multithreaded processor 12 also includes a central controller 20 that assists in loading micro code control for other resources of the hardware-based multithreaded processor 12 and performs other general purpose computer type functions such as handling protocols, exceptions, extra support for packet processing where the micro engines 22 pass the packets off for more detailed processing such as in boundary conditions. In one embodiment, the processor 20 is a Strong Arm® (Arm is a trademark of ARM Limited, United Kingdom) based architecture. The general-purpose microprocessor 20 has an operating system. Through the operating system the processor 20 can call functions to operate on micro engines 22a-22f. The processor 20 can use any supported operating system, preferably a real time operating system. For the core processor 20 implemented as Strong Arm architecture, operating systems such as, Microsoft-NT real-time, VXWorks and  $\mu$ CUS, a freeware operating system available over the Internet, can be used.

Functional micro engines (micro engines) 22a-22f each maintain program counters in hardware and states associated with the program counters. Effectively, a corresponding number of sets of threads can be simultaneously active on each of the micro engines 22a-22f while only one is actually operating at any one time.

In an embodiment, there are six micro engines 22a-22f as shown. Each micro engine 22a-22f has capabilities for processing four hardware threads. The six micro engines 22a-22f operate with shared resources including memory system 16 and bus interfaces 24 and 28. The memory system 16 includes a Synchronous Dynamic Random Access Memory (SDRAM) controller 26a and a Static Random Access Memory (SRAM) controller 26b. SDRAM memory 16a and SDRAM controller 26a are typically used for processing large volumes of data, e.g., processing of network payloads from network

packets. The SRAM controller 26b and SRAM memory 16b are used in a networking implementation for low latency, fast access tasks, e.g., accessing look-up tables, memory for the core processor 20, and so forth.

The six micro engines 22a-22f access either the SDRAM 16a or SRAM 16b based on characteristics of the data. Thus, low latency, low bandwidth data is stored in and fetched from SRAM 16b, whereas higher bandwidth data for which latency is not as important, is stored in and fetched from SDRAM 16a. The micro engines 22a-22f can execute memory reference instructions to either the SDRAM controller 26a or SRAM controller 16b.

Advantages of hardware multithreading can be explained by SRAM or SDRAM memory accesses. As an example, an SRAM access requested by a Thread\_0, from a micro engine will cause the SRAM controller 26b to initiate an access to the SRAM memory 16b. The SRAM controller 26b controls arbitration for the SRAM bus, accesses the SRAM 16b, fetches the data from the SRAM 16b, and returns data to a requesting micro engine 22a-22f. During an SRAM access, if the micro engine, e.g., micro engine 22a, had only a single thread that could operate, that micro engine would be dormant until data was returned from the SRAM 16b. By employing hardware context swapping within each of the micro engines 22a-22f, the hardware context swapping enables other contexts with unique program counters to execute in that same micro engine. Thus, another thread, e.g., Thread\_1 can function while the first thread, i.e., Thread\_0, is awaiting the read data to return. During execution, Thread\_1 may access the SDRAM memory 16a. While Thread\_1 operates on the SDRAM unit 16a, and Thread\_0 is operating on the SRAM unit 16b, a new thread, e.g., Thread\_2 can now operate in the micro engine 22a. Thread\_2 can operate for a certain amount of time until it needs to access memory or perform some other long latency operation, such as making an access to a bus interface. Therefore, simultaneously, the processor 12 can have a bus operation, SRAM operation and SDRAM operation all being completed or operated upon by one micro engine 22a and have one more thread available to process more work in the data path.

The hardware context swapping also synchronizes completion of tasks. For example, two threads could hit the same shared resource e.g., SRAM 16b. Each one of these separate functional units, e.g., the FBUS interface 28, the SRAM controller 26a, and the SDRAM controller 26b, when they complete a requested task from one of the micro engine thread contexts reports back a flag signaling completion of an operation. When

the micro engine receives the flag, the micro engine can determine which thread to turn on.

An application for the hardware-based multithreaded processor 12 is as a network processor. As a network processor, the hardware-based multithreaded processor 12  
5 interfaces to network devices such as a media access controller device e.g., a 10/100BaseT Octal MAC 13a or a Gigabit Ethernet device 13b. In general, as a network processor, the hardware-based multithreaded processor 12 can interface to any type of communication device or interface that receives/sends large amounts of data. Communication system 10 functioning in a networking application could receive network  
10 packets from the devices 13a, 13b and process those packets in a parallel manner. With the hardware-based multithreaded processor 12, each network packet can be independently processed.

Another example for use of processor 12 is a print engine for a postscript processor or as a processor for a storage subsystem, e.g., Redundant Array of Independent  
15 Disk (RAID) storage, a category of disk drives that employs two or more drives in combination for fault tolerance and performance. A further use is as a matching engine. In the securities industry for example, the advent of electronic trading requires the use of electronic matching engines to match orders between buyers and sellers. These and other parallel types of tasks can be accomplished utilizing the system 10.

20 The processor 12 includes the bus interface 28 that couples the processor to the second bus 18. In an embodiment, bus interface 28 couples the processor 12 to the FBUS (FIFO bus) 18. The FBUS interface 28 is responsible for controlling and interfacing the processor 12 to the FBUS 18. The FBUS 18 is a 64-bit wide FIFO bus, used to interface to Media Access Controller (MAC) devices, e.g., 10/100 Base T Octal MAC 13a.

25 The processor 12 includes a second interface e.g., PCI bus interface 24, that couples other system components that reside on the PCI 14 bus to the processor 12. The PCI bus interface 24 provides a high-speed data path 24a to memory 16, e.g., SDRAM memory 16a. Through PCI bus interface 24 data can be moved quickly from the SDRAM 16a through the PCI bus 14, via direct memory access (DMA) transfers. The hardware  
30 based multithreaded processor 12 supports image transfers. The hardware based multithreaded processor 12 can employ DMA channels so if one target of a DMA transfer is busy, another one of the DMA channels can take over the PCI bus 14 to deliver information to another target to maintain high processor 12 efficiency. Additionally, the

PCI bus interface 24 supports target and master operations. Target operations are operations where slave devices on bus 14 access SDRAMs through reads and writes that are serviced as a slave to a target operation. In master operations, the processor core 20 sends data directly to or receives data directly from the PCI interface 24.

5        Each of the functional units 22 is coupled to one or more internal buses. As described below, the internal buses are dual, 32 bit buses (i.e., one bus for read and one for write). The hardware-based multithreaded processor 12 also is constructed such that the sum of the bandwidths of the internal buses in the processor 12 exceed the bandwidth of external buses coupled to the processor 12. The processor 12 includes an internal core  
10        processor bus 32, e.g., an ASB Advanced System Bus (ASB), that couples the processor core 20 to the memory controller 26a, 26b and to an ASB translator 30, described below. The ASB bus 32 is a subset of the so-called Advanced Microcontroller Bus Architecture (AMBA) bus that is used with the Strong Arm processor core 20. AMBA is an open  
15        standard, on-chip bus specification that details a strategy for the interconnection and management of functional blocks that makes up a System-on-chip (SoC). The processor 12 also includes a private bus 34 that couples the micro engine units 22 to SRAM  
20        controller 26b, ASB translator 30 and FBUS interface 28. A memory bus 38 couples the memory controller 26a, 26b to the bus interfaces 24 and 28 and memory system 16 including flashrom 16c that is used for boot operations and so forth.

20        Referring to FIG. 2, each of the micro engines 22a-22f includes an arbiter that examines flags to determine the available threads to be operated upon. Any thread from any of the micro engines 22a-22f can access the SDRAM controller 26a, SDRAM  
25        controller 26b or FBUS interface 28. The memory controllers 26a and 26b each include queues to store outstanding memory reference requests. The queues either maintain order of memory references or arrange memory references to optimize memory bandwidth. For  
30        example, if a thread\_0 has no dependencies or relationship to a thread\_1, there is no reason that thread\_1 and thread\_0 cannot complete their memory references to the SRAM unit 16b out of order. The micro engines 22a-22f issue memory reference requests to the memory controllers 26a and 26b. The micro engines 22a-22f flood the memory  
30        subsystems 26a and 26b with enough memory reference operations such that the memory subsystems 26a and 26b become the bottleneck for processor 12 operation.

If the memory subsystem 16 is flooded with memory requests that are independent in nature, the processor 12 can perform memory reference sorting. Memory reference



sorting improves achievable memory bandwidth. Memory reference sorting, as described below, reduces dead time or a bubble that occurs with accesses to SRAM 16b. With memory references to SRAM 16b, switching current direction on signal lines between reads and writes produces a bubble or a dead time waiting for current to settle on  
 5 conductors coupling the SRAM 16b to the SRAM controller 26b.

That is, the drivers that drive current on the bus need to settle out prior to changing states. Thus, repetitive cycles of a read followed by a write can degrade peak bandwidth. Memory reference sorting allows the processor 12 to organize references to memory such that long strings of reads can be followed by long strings of writes. This  
 10 can be used to minimize dead time in the pipeline to effectively achieve closer to maximum available bandwidth. Reference sorting helps maintain parallel hardware context threads. On the SDRAM 16a, reference sorting allows hiding of pre-charges from one bank to another bank. Specifically, if the memory system 16b is organized into an odd bank and an even bank, while the processor is operating on the odd bank, the memory  
 15 controller can start pre-charging the even bank. Pre-charging is possible if memory references alternate between odd and even banks. By ordering memory references to alternate accesses to opposite banks, the processor 12 improves SDRAM bandwidth. Additionally, other optimizations can be used. For example, merging optimizations where operations that can be merged, are merged prior to memory access, open page  
 20 optimizations where by examining addresses an opened page of memory is not reopened, chaining, as will be described below, and refreshing mechanisms, can be employed.

The FBUS interface 28 supports Transmit and Receive flags for each port that a MAC device supports, along with an Interrupt flag indicating when service is warranted. The FBUS interface 28 also includes a controller 28a that performs header processing of  
 25 incoming packets from the FBUS 18. The controller 28a extracts the packet headers and performs a micro programmable source/destination/protocol hashed lookup (used for address smoothing) in SRAM 16b. If the hash does not successfully resolve, the packet header is sent to the processor core 20 for additional processing. The FBUS interface 28 supports the following internal data transactions:

30

FBUS unit	(Shared bus SRAM)	to/from micro engine.
FBUS unit	(via private bus)	writes from SDRAM Unit.
FBUS unit	(via Mbus)	Reads to SDRAM.

The FBUS 18 is a standard industry bus and includes a data bus, e.g., 64 bits wide and sideband control for address and read/write control. The FBUS interface 28 provides the ability to input large amounts of data using a series of input and output FIFOs 29a-29b. From the FIFOs 29a-29b, the micro engines 22a-22f fetch data from or command the SDRAM controller 26a to move data from a receive FIFO in which data has come from a device on bus 18, into the FBUS interface 28. The data can be sent through memory controller 26a to SDRAM memory 16a, via a direct memory access. Similarly, the micro engines can move data from the SDRAM 26a to interface 28, out to FBUS 18, via the FBUS interface 28.

Data functions are distributed amongst the micro engines 22. Connectivity to the SRAM 26a, SDRAM 26b and FBUS 28 is via command requests. A command request can be a memory request or a FBUS request. For example, a command request can move data from a register located in a micro engine 22a to a shared resource, e.g., an SDRAM location, SRAM location, flash memory or some MAC address. The commands are sent out to each of the functional units and the shared resources. However, the shared resources do not need to maintain local buffering of the data. Rather, the shared resources access distributed data located inside of the micro engines 22a-22f. This enables micro engines 22a-22f, to have local access to data rather than arbitrating for access on a bus and risk contention for the bus. With this feature, there is a zero cycle stall for waiting for data internal to the micro engines 22a-22f.

The data buses, e.g., ASB bus 30, SRAM bus 34 and SDRAM bus 38 coupling these shared resources, e.g., memory controllers 26a and 26b, are of sufficient bandwidth such that there are no internal bottlenecks. In order to avoid bottlenecks, the processor 12 has an bandwidth requirement where each of the functional units is provided with at least twice the maximum bandwidth of the internal buses. As an example, the SDRAM 16a can run a 64 bit wide bus at 83 MHz. The SRAM data bus could have separate read and write buses, e.g., could be a read bus of 32 bits wide running at 166 MHz and a write bus of 32 bits wide at 166 MHz. That is, in essence, 64 bits running at 166 MHz which is effectively twice the bandwidth of the SDRAM.

The core processor 20 also can access the shared resources. The core processor 20 has a direct communication to the SDRAM controller 26a to the bus interface 24 and to SRAM controller 26b via bus 32. However, to access the micro engines 22a-22f and

transfer registers located at any of the micro engines 22a-22f, the core processor 20 access the micro engines 22a-22f via the ASB Translator 30 over bus 34. The ASB translator 30 can physically reside in the FBUS interface 28, but logically is distinct. The ASB Translator 30 performs an address translation between FBUS micro engine transfer register locations and core processor addresses (i.e., ASB bus) so that the core processor 20 can access registers belonging to the micro engines 22a-22f.

Although micro engines 22a-22f can use the register set to exchange data as described below, a scratchpad memory 27 is also provided to permit micro engines 22a-22f to write data out to the memory for other micro engines to read. The scratchpad 27 is coupled to bus 34.

The processor core 20 includes a RISC core 50 implemented in a five stage pipeline performing a single cycle shift of one operand or two operands in a single cycle, provides multiplication support and 32 bit barrel shift support. This RISC core 50 is a standard Strong Arm® architecture but it is implemented with a five-stage pipeline for performance reasons. The processor core 20 also includes a 16-kilobyte instruction cache 52, an 8-kilobyte data cache 54 and a prefetch stream buffer 56. The core processor 20 performs arithmetic operations in parallel with memory writes and instruction fetches. The core processor 20 interfaces with other functional units via the ARM defined ASB bus. The ASB bus is a 32-bit bi-directional bus 32.

Referring to FIG. 3, an exemplary one of the micro engines 22a-22f, e.g., micro engine 22f, is shown. The micro engine 22f includes a control store 70, which, in one implementation, includes a RAM of here 1,024 words of 32 bit. The RAM stores a micro program (not shown). The micro program is loadable by the core processor 20. The micro engine 22f also includes controller logic 72. The controller logic 72 includes an instruction decoder 73 and program counter (PC) units 72a-72d. The four micro program counters 72a-72d are maintained in hardware. The micro engine 22f also includes context event switching logic 74. Context event logic 74 receives messages (e.g., SEQ\_#\_EVENT\_RESPONSE; FBI\_EVENT\_RESPONSE; SRAM\_#\_EVENT\_RESPONSE; SDRAM\_#\_EVENT\_RESPONSE; and ASB\_#\_EVENT\_RESPONSE) from each one of the shared resources, e.g., SRAM 26a, SDRAM 26b, or processor core 20, control and status registers, and so forth. These messages provide information on whether a requested function has completed. Based on whether or not a function requested by a thread has completed and signaled completion, the thread

needs to wait for that completion signal, and if the thread is enabled to operate, then the thread is placed on an available thread list (not shown). The micro engine 22f can have a maximum of four threads available.

In addition to event signals that are local to an executing thread, the micro engines 22a-22f employ signaling states that are global. With signaling states, an executing thread can broadcast a signal state to all micro engines 22a-22f, e.g., Receive Request Available (RRA) signal, any and all threads in the micro engines 22a-22f can branch on these signaling states. These signaling states can be used to determine availability of a resource or whether a resource is due for servicing.

The context event logic 74 has arbitration for the four threads. In an embodiment, the arbitration is a round robin mechanism. Other techniques could be used including priority queuing or weighted fair queuing. The micro engine 22f also includes an execution box (EBOX) data path 76 that includes an arithmetic logic unit (ALU) 76a and general-purpose register set 76b. The ALU 76a performs arithmetic and logical functions as well as shift functions. The register set 76b has a relatively large number of general-purpose registers. In an embodiment, there are 64 general-purpose registers in a first bank, Bank A and 64 in a second bank, Bank B. The general-purpose registers are windowed so that they are relatively and absolutely addressable.

The micro engine 22f also includes a write transfer register stack 78 and a read transfer stack 80. These registers 78 and 80 are also windowed so that they are relatively and absolutely addressable. Write transfer register stack 78 is where write data to a resource is located. Similarly, read register stack 80 is for return data from a shared resource. Subsequent to or concurrent with data arrival, an event signal from the respective shared resource e.g., the SRAM controller 26a, SDRAM controller 26b or core processor 20 will be provided to context event arbiter 74, which will then alert the thread that the data is available or has been sent. Both transfer register banks 78 and 80 are connected to the execution box (EBOX) 76 through a data path. In an embodiment, the read transfer register has 64 registers and the write transfer register has 64 registers.

Referring to FIG. 4, the micro engine data path maintains a 5-stage micro-pipeline 82. This pipeline includes lookup of microinstruction words 82a, formation of the register file addresses 82b, read of operands from register file 82c, ALU shift or compare operations 82d, and write-back of results to registers 82e. By providing a write-back data bypass into the ALU/shifter units, and by assuming the registers are implemented as a

register file (rather than a RAM), the micro engine 22f can perform a simultaneous register file read and write, which completely hides the write operation.

The SDRAM interface 26a provides a signal back to the requesting micro engine on reads that indicates whether a parity error occurred on the read request. The micro engine micro code is responsible for checking the SDRAM 16a read Parity flag when the micro engine uses any return data. Upon checking the flag, if it was set, the act of branching on it clears it. The Parity flag is only sent when the SDRAM 16a is enabled for checking, and the SDRAM 16a is parity protected. The micro engines 22 and the PCI Unit 14 are the only requestors notified of parity errors. Therefore, if the processor core 20 or FIFO 18 requires parity protection, a micro engine assists in the request. The micro engines 22a-22f support conditional branches.

Referring to FIG. 5, a format for arithmetic logic unit (ALU) instruction is shown. The micro engines 22 support an instruction set. The instruction set includes instructions that perform an operation on one or two operands and deposit the result into the destination register, and update ALU condition codes according to the result of the operation. Condition codes are lost during context swaps.

The computer instruction architecture set also includes a fast write (FAST\_WR) instruction. The FAST\_WR instruction for immediate data writes specified immediate data to a specified control and status register (CSR) by having write data specified directly in the instruction rather than in a transfer register. FAST\_WR writes the specified immediate data to the specified FBI CSR. This improves performance by eliminating the need for the FBI unit to pull the data from a transfer register. The FBI unit automatically shifts the immediate data into the appropriate register field corresponding to the thread that is writing the FAST\_WR data.

A format for the fast write instruction is: fast\_wr [immed\_data, csr\_addr], optional\_token, where a description of each of the fields follows.

The "immed\_data" field represents 10 bits of the immediate data to be written to the control and status register (CSR); valid immed\_data values are 0 through 0x3FF. The "csr\_addr" field represents the symbolic names that follow address the corresponding CSRs. The "optional\_token" field contains an "indirect\_ref" parameter that indicates overriding qualifiers or additional qualifiers, fully described below, are associated with this reference.

The 10-bit immediate data for FAST\_WRT includes the following fields. The "incr\_enq\_num1" and "incr\_enq\_num2" fields write a 1 to increment an enqueue sequence number by one. The enqueue sequence number is always incremented by one.

The "inter\_thd\_sig" field represents a thread number (0 - 23) of the thread to be signaled.

The 10-bit immediate data supplied with the instruction is shifted in two segments to the appropriate fields. Bits 6 through 0 are shifted left by an amount equal to the thread number writing the data. Bits 9 through 7 are always shifted into the BP2 through BP0 positions regardless of the micro engine writing the data.

The "self\_destruct" field specifies a bit position (0 to 31) that will be set. A "thread\_done" field represents a 2-bit message that is shifted into a position relative to the thread that is writing the message. The message is determined through software.

The "thread\_done\_incr1" and "thread\_done\_incr2" fields are the same as for the thread\_done register except that either "enqueue\_seq1" or "enqueue\_seq2" is incremented.

The "xmit\_validate" field represents the transmit FIFO element number (0 to 15) that is marked to indicate that the data is valid in this element.

The "indirect\_ref" field has the bits definitions and functions set out below:

20	Bits	Field	Description
	31	OV	If set, the UENG ADDR field overrides the default micro engine address implied by the FAST_WR command, which is the micro engine that issued the CSR reference.
25	30:28	UENG ADDR	Specifies the micro engine associated with the CSR reference. If bit [31] = 0, this field is ignored. Valid UENG ADDR values are 0 through 5.
	27:16	RES	Reserved. Returns 0 when read.
30	15	OV	If set, the FAST WRITE DATA field overrides the default micro engine data specified by fast_wr_data.

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- 14:5 FASTWRITEDATA Immediate data to be written to the  
CSR. Valid FAST WRITE DATA values are 0  
through 0x3FF. If bit [15] = 0, this field is ignored.
- 4:3 RES Reserved. Returns 0 when read.
- 5 2 OV If set, the CTX field overrides the  
default context implied by the FAST\_WR  
command.
- 1:0 CTX Specifies the context associated with  
the CSR reference. If bit [2] = 0, this field is  
ignored. Valid CTX values are 0 through 3.
- 10

- It is to be understood that while the invention has been described in conjunction  
with the detailed description thereof, the foregoing description is intended to illustrate and  
not limit the scope of the invention, which is defined by the scope of the appended claims.
- 15 Other aspects, advantages, and modifications are within the scope of the following  
claims.

WHAT IS CLAIMED IS:

1. A method of operating a processor comprising:  
receiving data in a processing thread having a processing thread number; and  
loading the data into a register having a register address corresponding to the  
processing thread number.
- 5 2. The method of claim 1 wherein the register is a control and status register (CSR).
3. The method of claim 2 wherein the status and control register is contained in a 64-  
bit wide first-in first-out (FIFO) bus.
4. The method of claim 3 wherein the FIFO bus interfaces with Media Access  
Controller (MAC) devices.
- 10 5. The method of claim 1 wherein the data represents values hexadecimal mask 0 to  
hexadecimal mask 0x3FF.
6. The method of claim 1 wherein the processing thread represents processing in a  
micro engine of a multi-threaded processor.
7. The method of claim 1 shifting comprises:  
15 shifting a first portion of the data by an amount equal to the processing thread  
number; and  
shifting second portion of the data into a breakpoint (BP) register 2 to a BP  
register 0.
8. The method of claim 1 wherein receiving the data further comprises receiving a  
20 token.
9. The method of claim 8 wherein the token represents overriding qualifiers.
10. The method of claim 8 wherein the token is a 32-bit word.



11. The method of claim 10 wherein a token format comprises:  
an OV field in bit 31;  
an micro engine (UENG) ADDR field in bits 30:28;  
a reserved field in bits 27:16;  
5 an OV field in bit 15;  
a fast write data field in bits 14:5;  
a reserved field in bits 4:3;  
an OV field in bit 2; and  
a CTX field in bits 1:0.
- 10 12. The method of claim 11 wherein a micro engine address overrides a default micro engine address if bit 31 is set.
13. The method of claim 11 wherein bits 30:28 specify a micro engine associated with a control and status register (CSR).
14. The method of claim 11 wherein bits 27:16 return 0 when read.
- 15 15. The method of claim 11 wherein a micro engine address overrides a default micro engine address if bit 15 is set.
16. The method of claim 11 wherein bits 14:5 represent valid data to be written to a control and status register (CSR).
17. The method of claim 11 wherein bits 4:3 return 0 when read.
- 20 18. The method of claim 11 wherein a context (CTX) field overrides a default context if bit 2 is set.
19. The method of claim 11 wherein bits 1:0 specify a context associated with a control and status register (CSR) reference.

20. A computer program product, disposed on a computer readable medium, the program comprising instructions for causing a computer to:
- receive data in a processing thread having a processing thread number; and
  - load the data into a register corresponding to the processing thread number.
- 5 21. The computer program product of claim 20 wherein the register field is a control and status register (CSR).
22. The computer program product of claim 21 wherein the status and control register is contained in a 64-bit wide first-in first-out (FIFO) bus.
23. The computer program product of claim 22 wherein the FIFO bus interfaces with  
10 Media Access Controller (MAC) devices.
24. The computer program product of claim 20 wherein the data represents values hexadecimal mask 0 to hexadecimal mask 0x3FF.
25. The computer program product of claim 20 wherein the processing thread represents processing in a micro engine of a multi-threaded processor.
- 15 26. The computer program product of claim 20 further comprising instructions for causing the computer to:
- shift a first portion of the data left by an amount equal to the processing thread number; and
  - shift a second portion of the data into a breakpoint (BP) register 2 to a BP register  
20 0.
27. The computer program product of claim 20 further comprising an instruction for causing the computer to receive a token.
28. The computer program product of claim 27 wherein the token represents overriding qualifiers.
- 25 29. The computer program product of claim 27 wherein the token is a 32-bit word.

30. The computer program product of claim 29 wherein a token format comprises:  
an OV field in bit 31;  
an micro engine (UENG) ADDR field in bits 30:28;  
a reserved field in bits 27:16;  
5 an OV field in bit 15;  
a fast write data field in bits 14:5;  
a reserved field in bits 4:3;  
an OV field in bit 2; and  
a CTX field in bits 1:0.
- 10 31. The computer program product of claim 30 wherein a micro engine address overrides a default micro engine address if bit 31 is set.
32. The computer program product of claim 30 wherein bits 30:28 specify a micro engine associated with a control and status register (CSR).
33. The computer program product of claim 30 wherein bits 27:16 return 0 when read.
- 15 34. The computer program product of claim 30 wherein a micro engine address overrides a default micro engine address if bit 15 is set.
35. The computer program product of claim 30 wherein bits 14:5 represent valid data to be written to a control and status register (CSR).
36. The computer program product of claim 30 wherein bits 4:3 return 0 when read.
- 20 37. The computer program product of claim 30 a context (CTX) field overrides a default context if bit 2 is set.
38. The computer program product of claim 30 wherein bits 1:0 specify a context associated with a control and status register (CSR) reference.
- 25 A method of operating a processor including receiving data in a processing thread having a processing thread number and shifting the data into a register corresponding to the processing thread number.

ABSTRACT

A method of operating a processor (12) including receiving data in a processing thread having a processing thread number and shifting the data into a register corresponding to the processing thread number.

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FAST WRITE INSTRUCTION FOR MICRO ENGINE USED IN  
MULTITHREADED PARALLEL PROCESSOR  
ARCHITECTURE

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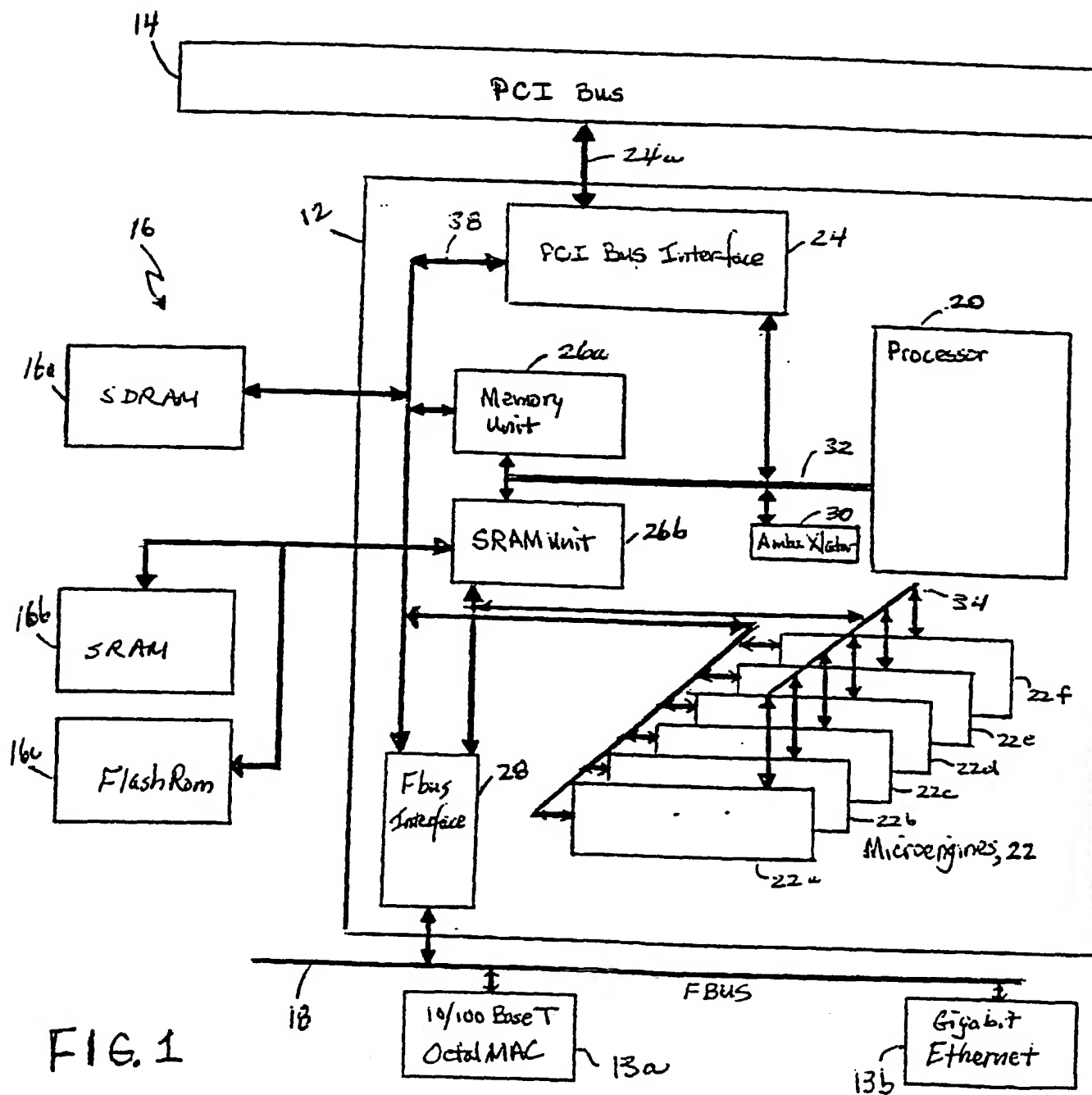
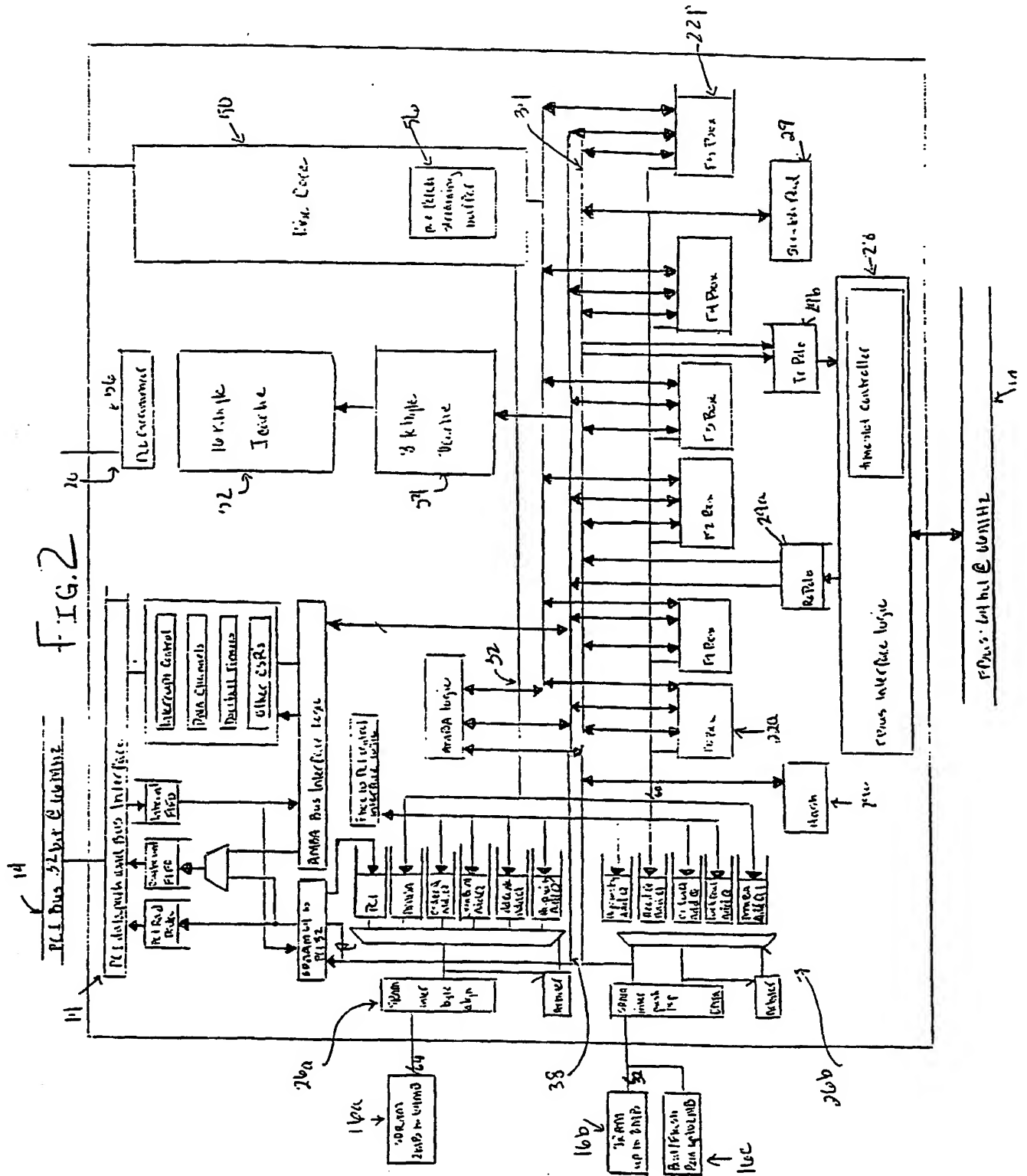
10

FIG. 1

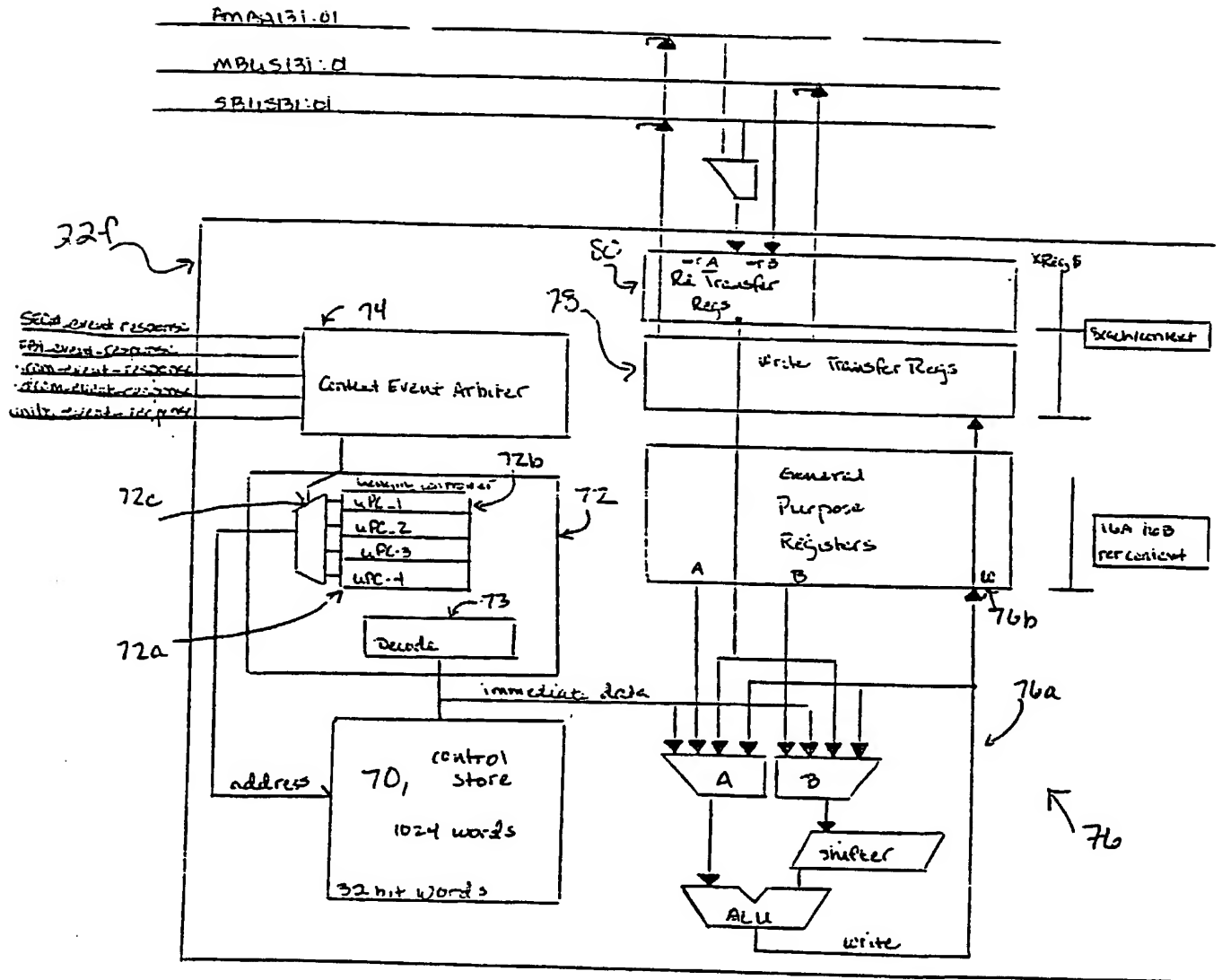


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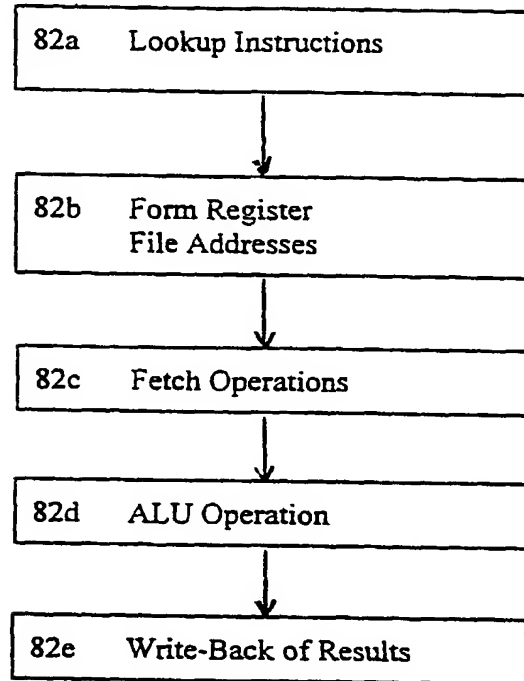
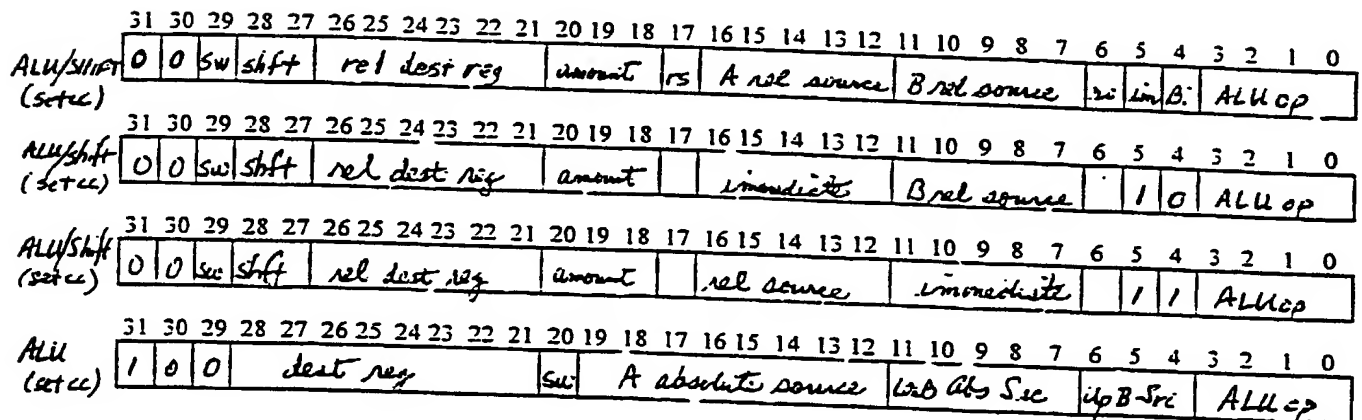


FIG. 4





Shift Decode:

(rs, r0) decode ([31:0] shifts into [63:32] and take [63:32]):

- 00 = left rotate
- 01 = right shift (32-ShfAmt = Right Shift Amt)
- 10 = left shift
- 11 = double shift (upper A-op shifts into lower B-op)

==> "left rotate" of zero gives zero shift (therwise zero amount signifies indirect shift)

ALU-OP decode:

0000 = B	0100 = ~A&B (~and)	1000 = A-B	1100 = A+B(8)
0001 = ~B	0101 = XOR	1001 = B-A	1101 = A+B(16)
0010 = A&B (and)	0110 = OR	1010 =	1110 = A+B
0011 = A&~B (and~)	0111 = mul-stuff	1011 =	1111 = A+B+Cin

FIG. 5

**COMBINED DECLARATION AND POWER OF ATTORNEY**

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled FAST WRITE INSTRUCTION FOR MICRO ENGINE USED IN MULTITHREADED PARALLEL PROCESSOR ARCHITECTURE, the specification of which:

☐ is attached hereto.

☒ was filed on February 22, 2002 as Application Serial No. 10/069,352 and was amended on \_\_\_\_\_.

☐ was described and claimed in PCT International Application No. \_\_\_\_\_ filed on \_\_\_\_\_ and as amended under PCT Article 19 on \_\_\_\_\_.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose all information I know to be material to patentability in accordance with Title 37, Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed:

<u>Country</u>	<u>Application No.</u>	<u>Filing Date</u>	<u>Priority Claimed</u>
WIPO	PCT/US00/24000	08/31/2000	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Yes <input type="checkbox"/> No

I hereby appoint the following attorneys and/or agents to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

Scott C. Harris, Reg. No. 32,030

David L. Feigenbaum, Reg. No. 30,378

Christina Sperry, Reg. No. 47,106

Denis G. Maloney, Reg. No. 29,670

Kenneth F. Kozik, Reg. No. 36,572

Paul A. Pysher, Reg. No. 40,780

Address all telephone calls to DENIS G. MALONEY at telephone number (617) 542-5070.

Address all correspondence to DENIS G. MALONEY at:

FISH & RICHARDSON P.C.

225 Franklin Street

Boston, Massachusetts 02110-2804

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patents issued thereon.

**Combined Declaration and Power of Attorney**

Page 2 of 8 Pages

100 Full Name of Inventor: GILBERT WOLRICHInventor's Signature: *Gilbert Wolrich*Date: July 15, 2002Residence Address: Framingham, MACitizenship: United StatesPost Office Address: 4 Cider Mill Road  
Framingham, MA 01701200 Full Name of Inventor: MATTHEW J. ADILETTAInventor's Signature: *Matthew J. Adiletta*Date: July 19, 2002Residence Address: Worcester, MACitizenship: United StatesPost Office Address: 20 Monticello Drive  
Worcester, MA 01603300 Full Name of Inventor: WILLIAM R. WHEELERInventor's Signature: *William R. Wheeler*Date: 7/15/02Residence Address: Southborough, MACitizenship: United StatesPost Office Address: 9 Darlene Drive  
Southborough, MA 01772400 Full Name of Inventor: DEBRA BERNSTEINInventor's Signature: *Debra Bernstein*Date: 7/15/02Residence Address: Sudbury, MACitizenship: United StatesPost Office Address: 321 Old Lancaster Road  
Sudbury, MA 01776500 Full Name of Inventor: DONALD F. HOOPERInventor's Signature: *Donald F. Hooper*Date: 7/15/02Residence Address: Shrewsbury, MACitizenship: United StatesPost Office Address: 19 Main Circle  
Shrewsbury, MA 01545